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ABSTRACT

This unit provides an introduction to basic concepts which are applicable to all biological treatment systems. It consists of three lessons which focus on: the microorganisms found in biological systems; the factors that affect the growth and health of biological systems; and the interrelationship between groups of microorganisms, their competition, predominance, and symbiosis. The instructor's guide for the unit includes: (1) an overview of the unit; (2) lesson plans; (3) lecture outlines (keyed to a set of slides designed for use with the lessons); (4) a student worksheet for each lesson (with answers); and (5) two copies of a final quiz (with and without answers). (JN)

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Biological Treatment Process Control

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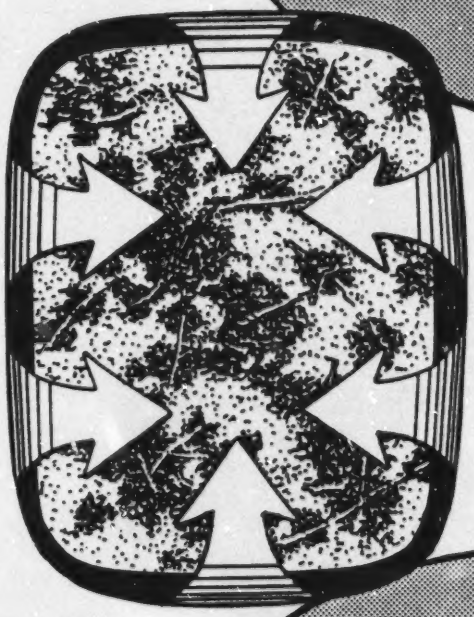
Biological Concepts



Instructor's Guide

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SE 015 345

Linn-Benton Community College
Albany, Oregon
1984

BIOLOGICAL TREATMENT PROCESS CONTROL

CONCEPTS OF BIOLOGICAL TREATMENT

INSTRUCTOR'S GUIDE

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1984

CONCEPTS OF BIOLOGICAL TREATMENT

Instructor's Guide

Table of Contents

	Page #
Overview of Lessons	I-CB-1
Lesson Plans	I-CB-1
Lecture Outlines	I-CB-3
Answers to Worksheets	I-CB-12
Final Quiz	I-CB-17
Answers to Final Quiz	I-CB-23

CONCEPTS OF BIOLOGICAL TREATMENT

Overview

This section is intended to be used introductory to the more specific biological treatment processes that follow. Material in this section is basic and applies to all biological treatment systems. This section could also be used in conjunction with single lessons. The section is presented in three lessons: #1 The Microorganisms; #2 Environmental Factors; and #3 Population Dynamics. Lesson 1 is a survey of the microorganisms found in biological systems. Lesson 2 deals with the factors that affect the growth and health of biological systems. Lesson 3 covers the interrelationship between groups of microorganisms, their competition, predominance and symbiosis.

Lesson Plans

Lesson 1 - The Microorganisms

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 45 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (15 min)

Lesson 2 - Environmental Factors

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 30 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (10 min)

Lesson 3 - Population Dynamics

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 30 min)
- Assign worksheet (10 min)

- Correct and discuss worksheet (10 min)
- Assign final quiz (15 min)

CONCEPTS OF BIOLOGICAL TREATMENT

Lecture Outlines

Lesson 1 - The Microorganisms

Slide #	
#1 & #2	Title & Credit Slides
#3	The Biological System
	The flow
	The sound
	The "dirty, foaming water"
	The "Bugs"
#4, #5, #6	To "See" the "Bugs" - Consider the Objectives of Wastewater Treatment
#7	Protect receiving stream
	Prevent oxygen depletion
#8	Reduce food material in waste
	The "Bugs" use food in waste
#9	Oxygen supplied
#10	"Bugs" eat and eat
	Clean water discharged
	Drawback - "Bugs" grow - too many
#11, #12	Excess must be separated and disposed of
	The Operator's main job
#13, #14	Keep "bugs" comfortable and happy
	Must have enough to eat
	Correct environment
	Free of disease
	Free of poison
	Free of predators

What are these "bugs"?

#15 A mixed biological system

- Workers
- Troublemakers
- Freeloaders

#16 You can find -

- Bacteria
- Protozoa
- Viruses
- Fungi
- Algae
- Other higher forms

#17 Bacteria

- Most numerous
- Most important to treatment
- Single-cells
  1 micron (micrometer; 10^{-6} m) long

#18 Shapes

- cocci - spheres
- bacilli - rods
- spirals

#19 Motility

- gliding
- flagella

#20 Capsules

#21 Protozoa

- Microscopic animals
- Single-cells
- Much larger than bacteria
- More complex than bacteria

#22 4 types

#23 Amoeba (Sarcodina)

- no definite shape
- false feet
- amoeboid movement

Ciliates (Ciliata)

#24 Free-swimming

- cilia
- ovoid to pear-shaped

#25 Stalked

- cup-shaped cell with a stalk
- cilia around "cup"

#26 Flagellates (Mastigophora)

- Flagella
- Free-swimming

#27 Suctoreans (Suctoria)

- Rigid tentacles
- Stalked

#28 Viruses

- Strictly parasitic
- Lack metabolic systems
- Extremely small
- Genetic material and a protective coat

#29 Fungi

- Similar to bacteria

#30 Algae

- Microscopic plants
- Photosynthetic

#31 Higher forms

- Rotifers
- Snails
- Worms
- Insect larvae and adults
- Crustaceans

#32,#33 Review Slides

Lesson 2 - Environmental Factors

Slide #	
#1 & #2	Title and Credit Slides
	Review of Biological Process
#3	What does the operator really see?
	Population of mixed microorganisms
#4	Organisms consume organics, use oxygen and remove dissolved and suspended solids before they get to the receiving stream
#5	The health of the population depends on several factors:
	Oxygen
	Nutrients
	Flow
	Temperature
	pH
	Toxics
#6	Outline Slide - Food
#7	The food (nutrients) comes from many sources in the collection system
#8	The nutrients (organic food) directly affect the amount of growth; number of microorganisms
	More cells with more food
	Typical batch growth curve
#9	Increase in microorganisms vs time after a single dose of food
#10	Log growth phase - exponential growth unlimited by food supply
#11	Declining growth phase - food starts to limit the rate of cell increase

#12 Endogenous growth phase - food is limiting; bacteria use stored nutrients to survive

#13 Food to microorganism ratio - F/M ratio - high at first then become small

#14 Other nutrient requirements

- How easily are the organics used?
- Inorganic minerals and trace elements

#15 Outline Slide - Hydraulic Load

#16 Affects solids and nutrient concentration

- Low flow - high concentration
- High flow - low concentration

#17 Affects detention time

- Low flow - long DT
- High flow - short DT

#18 Outline Slide - Oxygen

#19 Aerobic conditions - use free, dissolved oxygen

#20 Anaerobic conditions - use chemically bound oxygen

#21 Facultative - aerobic or anaerobic conditions - bacteria can use either form of oxygen

#22

- Under aerobic conditions aerobic and facultative organisms present
- Under anaerobic conditions, anaerobic and facultative organisms present

#23 If oxygen is present the facultative organisms will use aerobic respiration and convert organics at a faster rate

#24 Outline Slide - Temperature

#25 Three temperature growth ranges

- thermophilic
- mesophilic
- psychrophilic

#26 Temperature vs growth rate

- Organisms have an optimum growth temperature

#27

- Efficiency increases as temperature increases
- Growth rate doubles for each 10 degrees increase

#28 Outline Slide - pH

#29 Most organisms prefer pH near neutral

Fungi grow well at lower pH

#30 pH vs growth rate

- Organisms have an optimum growth pH

#31 Outline Slide - Toxics

#32 Toxics can inhibit growth or completely stop growth

#33 Review Slide of growth factors

#34 All of these factors affect the bio-system

#35 The operator must control these growth factors in order to keep the bio-system going down the path of optimum treatment

#36 It is only with a knowledge of these growth factors that the operator can truly "see" what is going on in the treatment plant

Lesson 3 - Population Dynamics

Slide #	
#1 & #2	Title and Credit Slides
#3	Population Dynamics - The changes that occur within the microorganism population as a result of environmental factors
#4	Predominance - The organisms that get the most to eat and do it the fastest and most efficiently will predominate
	Efficiency
#5	Aerobic metabolism is more efficient; aerobic organisms will predominate when free oxygen is present
#6, #7, #8	Anaerobic metabolism uses bound oxygen; less efficient
	Competition
#9	If there is one group of organisms alone they will use food at a certain efficiency
#10	If a second group is present the one that is the most efficient at converting the same food will predominate
#11	If two organisms are present the one that converts food the fastest will predominate
#12	If two groups use the same food but one is much more efficient the second may get left out all together
#13	unless they can switch to a second choice of food. Then they will survive also.
	Growth Pressures
#14	Temperature
	A shift in temperature may favor the increase in one type of organism

#15 pH

A shift in pH may favor the increase in one or the decrease in another type of organism

#16 Dissolved Oxygen

If dissolved oxygen is lost the population will shift from aerobes and facultative to facultative and anaerobes

#17 Toxics

The presence of toxic materials may stop the growth of some types and inhibit others; some may not be greatly affected

#18 Fixed Film and Suspended growth systems are both affected by environmental growth pressures

#19 The Aquatic Food Chain

Bacteria are at the bottom, followed by protozoa, fungi, algae, insect larvae and higher aquatic organisms

#20 The protozoa vs bacteria growth curve

Can be used to assess the condition of the bacteria in activated sludge

As food decrease protozoa appear in the following order: amoeba, flagellates, free-swimming ciliates, stalked ciliates, and rotifers

#21 The algae/bacteria symbiosis

Algae use energy from the sun, carbon dioxide and minerals from the bacteria to produce oxygen; the bacteria use the oxygen from the algae and organic material

#22 Primary/Secondary Predominance

Primary Predominance -
Hard to digest foods can be metabolized by bacteria that have been acclimated to that special food source

Secondary Predominance -
After the primary organisms have partially metabolized the material the less specialized organisms can deal with the material

#23 Dynamic Equilibrium

Keeping a changing system in balance

#24 Energy in must equal the energy going out of the system

#25 Review of Population Dynamics

Answers to Worksheet 1 - The Microorganisms

1. We use the term "bugs" to mean all of the microorganisms in the biological treatment system.

2. The primary objective of wastewater treatment is to:
   prevent the degradation of the receiving stream by reducing the amount of organic material discharged to it.

3. When organic material is allowed to enter a stream the natural biological activity in the stream depletes the oxygen.

4. In biological treatment processes, with the exception of anaerobic digestion, the bugs or microorganisms are supplied with air (oxygen) so they can consume the food in a controlled environment.

5. The only drawback to the bugs eating and eating is that they create excess solids (cells).

6. Name the five major groups of bugs typically found in biological treatment systems:

   bacteria

   protozoa

   viruses

   algae

   fungi

7. The microorganism which is responsible for the majority of the stabilization activity is the bacteria.

8. On the average bacteria are about 1 micron wide.

9. The three structural shapes of bacteria are:

   rod (bacillus)

   spheres (cocci)

   spirals

10. The slimy, gummy coat around some bacteria is called the capsule.

11. The protozoa are a group of microscopic animals.

12. The four major groups of protozoa found in biological treatment systems are:

    amoeba

    ciliates

    flagellates

    suctoria

13. Amoeba move about with the use of pseudopods or false feet.

14. The two types of ciliates are the free-swimming and the stalked.

15. The Mastigophora move about with the use of flagella.

16. The suctoria resemble the ciliates except they have tentacles instead of cilia.

17. The viruses are strictly parasitic because they have no enzyme systems.

18. The algae are true photosynthetic plants.

19. Four types of "higher" animal forms are frequently found in and around biological systems. These include:

    insect larvae

    rotifers

    worms

    snails

Answers to Worksheet 2 - Environmental Factors

1. The main "objective" of the microorganisms in the treatment system is to obtain food and energy for maintenance and reproduction.

2. The environmental factors that cause the microorganisms to react in some way are often called environmental pressures.

3. The food materials available to the microorganisms are mostly organic materials.

4. The phase of a bacterial growth curve in which the bacteria are increasing at a maximum rate is called the log growth phase.

5. The phase of the growth curve in which food is not available and the bacteria are utilizing energy stored within their own cells is called the endogenous phase.

6. The amount of liquid entering the system is called the hydraulic load.

7. Most organisms in the biological treatment processes use free dissolved oxygen. These are called aerobic organisms.

8. At times bacteria carry out anaerobic respiration in which they use chemically bound oxygen.

9. Many bacteria in biological systems are capable of using either aerobic or anaerobic respiration. These organisms are said to be facultative.

10. Microorganisms that thrive at about 35 degrees Celcius are called mesophilic organisms.

11. Microorganisms that prefer relatively high temperatures are called thermophilic organisms.

12. Most microorganisms in the biological treatment systems do well at a pH in the range of 6.5 to 8.5.

13. One group of microorganisms tend to prefer lower pH and high carbohydrate conditions. These are the fungi.

14. Large amounts of toxic or poisonous materials could actually kill (destroy) all the microorganisms in the system.

Answers to Worksheet 3 - Population Dynamics

1. The term population dynamics is used to describe the continuous fluctuations that occur with the many types of microorganisms in the system.

2. Predominance is established by the microorganisms that derive energy from the available food most efficiently.

3. The process of converting energy in the organic food to usable energy is called respiration.

4. As a result of the energy derived aerobically from the organics, new cells are produced along with two by-products: carbon dioxide and water.

5. Anaerobic respiration produces different by-products depending on the source of bound oxygen used. These are:

   for nitrate bound oxygen = nitrogen gas (N_2)

   for sulfate bound oxygen = hydrogen sulfide (H_2S)

   for carbon dioxide oxygen = methane (CH_4)

6. Anaerobic respiration will derive only about 15 percent as much energy from the same organics as from aerobic respiration.

7. The food (organics) provides energy and also raw (building) material needed to produce new cells.

8. Efficiency of converting food to usable energy can be accomplished either by converting organics rapidly or completely.

9. Name three growth pressures other than oxygen and food that can affect population predominance.

   temperature, pH, sunlight, salinity, toxic materials

10. At times one organism will prey upon a certain type of organism and at the same time be preyed upon by a third type. This is an example of the food chain.

11. Organisms at the bottom of the food chain are typically smaller, but in total have a larger mass.

12. Protozoa can be used to observe the conditions of the bacterial population because the protozoa feed on the bacteria.

13. During photosynthesis the algae utilize sunlight, inorganics, and carbon dioxide to produce new algae cells and oxygen.

14. The algae are provided with the inorganics and carbon dioxide by the bacteria in the system.

15. A healthy population of bacteria can be developed to act as primary predominance on almost any type of waste material.

CONCEPTS OF BIOLOGICAL TREATMENT

Final Quiz

MATCHING: Choose the best answer(s) for each of the following questions and place an "X" in the appropriate space.

1. When microorganisms in a treatment plant come into contact with food (organic material), they:

_____ a. eat and reproduce
_____ b. become aerobic
_____ c. become anaerobic
_____ d. die
_____ e. settle

2. Which of the following characteristics does NOT describe logarithmic growth:

_____ a. microorganisms grow and multiply at their maximum rate
_____ b. food is in excess
_____ c. continues until food begins to be used up
_____ d. common when there is a high F/M ratio (food:microorganism)
_____ e. slow growth rate

3. Declining growth occurs when:

_____ a. food is almost used up and growth rate slows down
_____ b. food is in excess
_____ c. microorganisms grow and multiply at their maximum rate
_____ d. microorganisms are in endogenous respiration
_____ e. there is a high F/M ratio (food:microorganism)

4. Endogenous growth phase occurs when:

_____ a. there is a low F/M ratio
_____ b. food is in excess
_____ c. microorganisms grow and multiply at their maximum rate
_____ d. there is a high F/M ratio
_____ e. microorganisms use up food reserves that is stored inside their cells

5. "Hydraulic load" refers to:

_____ a. the amount of food entering a system
_____ b. the amount of water entering a system
_____ c. the weight of water in a system
_____ d. the weight of organic material in a system
_____ e. the length of pipe in the collection system

6. Some bacteria obtain the oxygen they need from chemically bound compounds, and in fact, can't grow when free oxygen is present. These organisms are called:

_____ a. anaerobes
_____ b. aerobes
_____ c. microbes
_____ d. facultative
_____ e. filaments

7. Temperature is a growth pressure. As a general rule, as temperature goes up:

_____ a. growth rate slows down
_____ b. growth rate speeds up
_____ c. growth rate stays the same
_____ d. pH goes up
_____ e. pH goes down

8. Microorganisms that grow best at high temperatures are called:

_____ a. thermophillic
_____ b. mesophillic
_____ c. psychrophillic
_____ d. anaerobic
_____ e. aerobic

9. pH is a term which describes how acidic or basic a solution is. pH 7 is considered:

_____ a. acidic
_____ b. basic
_____ c. neutral

10. As waste materials break down in a stream:

_____ a. temperature goes down
_____ b. fish reproduce
_____ c. dissolved oxygen is consumed
_____ d. temperature goes up
_____ e. dissolved oxygen goes up

11. What group of microorganisms do the most work in a secondary treatment plant?

_____ a. viruses
_____ b. fungi
_____ c. worms
_____ d. bacteria
_____ e. protozoa

12. Bacteria are:

_____ a. single-celled
_____ b. multi-celled
_____ c. always aerobic
_____ d. visible to the naked eye
_____ e. always the same shape

13. Rod-shaped bacteria are also called:

_____ a. coccus
_____ b. spirillum
_____ c. bacillus
_____ d. vibrio
_____ e. sarcina

14. Protozoa are:

_____ a. usually about a hundred times bigger than bacteria
_____ b. about the same size as bacteria
_____ c. photosynthetic
_____ d. always non-motile
_____ e. responsible for doing the most work in secondary treatment

15. Which of the following does NOT apply to free-swimming ciliates:

_____ a. move with flagella
_____ b. usually ovoid to pear-shaped
_____ c. single-celled
_____ d. have fine "hair-like" appendages for locomotion
_____ e. are larger than bacteria

16. Which of the following does NOT apply to stalked ciliates:

_____ a. usually attached to something in the water (substrate)
_____ b. are single-celled
_____ c. may be colonial
_____ d. are common in biological treatment systems
_____ e. use flagella for locomotion

17. Which of the following does not apply to flagellates:

_____ a. also called Mastigophora
_____ b. are usually ovoid to pear-shaped
_____ c. single-celled
_____ d. use flagella for locomotion
_____ e. are covered with fine "hair-like" appendages for feeding

18. Which of the following characteristics does NOT apply to a virus:

_____ a. are strictly parasitic and lack the metabolic systems necessary to obtain energy on their own, or even reproduce by themselves.
_____ b. they steal energy and raw materials of their host.
_____ c. are about the same size as bacteria.
_____ d. are a hundred to a thousand times smaller than bacteria.
_____ e. they do very little work in secondary treatment

19. When one type of organism derives energy more efficiently than another type

_____ a. anaerobic respiration is occurring
_____ b. aerobic respiration is occurring
_____ c. the pH is too high
_____ d. predominance will occur
_____ e. one will die completely

20. By-products of anaerobic respiration include

_____ a. nitrogen gas
_____ b. nitrate
_____ c. hydrogen sulfide
_____ d. methane gas
_____ e. all of the above

21. Anaerobic respiration will derive about _____% as much energy from the same organic material as aerobic respiration.

_____ a. 5
_____ b. 10
_____ c. 15
_____ d. 25
_____ e. 50

22. Which of the following are environmental pressures that can cause predominance to shift?

_____ a. temperature
_____ b. pH
_____ c. sunlight
_____ d. salinity
_____ e. toxic materials

23. In the prey-predator relationship known as the food chain:

_____ a. those at the top of the chain are the ultimate prey.
_____ b. protozoa are lower than bacteria and algae.
_____ c. organisms at the bottom are typically smaller.
_____ d. those at the top are dependent upon those at the bottom.
_____ e. the mass of those at the bottom is greater than that of those at the top.

24. Which of the following is NOT true about the protozoa population dynamics in activated sludge?

_____ a. protozoa feed on bacteria
_____ b. amoeba and flagellates are found under high food availability
_____ c. rotifers are found at the same time that the bacterial population is maximum.
_____ d. stalked-ciliates begin to predominate as the food supply begins to diminish.
_____ e. free-swimming ciliates predominate at the same time as the bacteria are at maximum

25. In the algae-bacteria inter-relationship

_____ a. algae use sunlight for energy
_____ b. algae produce oxygen
_____ c. bacteria use organics
_____ d. bacteria provide dissolved inorganics, and carbon dioxide
_____ e. bacteria use carbon dioxide

Answers to Final Quiz

MATCHING: Choose the best answer(s) for each of the following questions and place an "X" in the appropriate space.

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____ e. are larger than bacteria

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____ b. they steal energy and raw materials of their host.
X c. are about the same size as bacteria.
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____ c. the pH is too high
X d. predominance will occur
____ e. one will die completely

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____ b. nitrate
X c. hydrogen sulfide
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____ b. 10
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____ d. 25
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X c. organisms at the bottom are typically smaller.
X d. those at the top are dependent upon those at the bottom.
X e. the mass of those at the bottom is greater than that of those at the top.

24. Which of the following is NOT true about the protozoa population dynamics in activated sludge?

____ a. protozoa feed on bacteria
____ b. amoeba and flagellates are found under high food availability
X c. rotifers are found at the same time that the bacterial population is maximum.
____ d. stalked-ciliates begin to predominate as the food supply begins to diminish.
____ e. free-swimming ciliates predominate at the same time as the bacteria are at maximum

25. In the algae-bacteria inter-relationship

__X__ a. algae use sunlight for energy
__X__ b. algae produce oxygen
__X__ c. bacteria use organics
__X__ d. bacteria prcvide dissolved inorganics, and carbon dioxide
____ e. bacteria use carbon dioxide